MINISTRY OF HEALTH OF UKRAINE
O.O. BOGOMOLETS NATIONAL MEDICAL UNIVERSITY

"Approved"
at the methodological conference of hygiene and ecology department
Head of the department
correspondent member of NAMS of Ukraine,
M.D. Bardov V.G._____

GUIDELINES
FOR STUDENTS

Subject	Hygiene and ecology
Module № 1	Assessment of the environment and its impact on the population health
Submodule № 2	Municipal hygiene
Topic of the lesson	Hygienic significance of physical factors in settlements conditions.
Course	6
Faculty	medical
Author	asst. prof Vavrinevych O.P., asst. prof. Zagorodniuk K.Yu.

Kiev

1. Learning objective

1.1. Substantiate the hygienic significance of microclimate for different premises (residential, public/social, industrial) and master the measurement and hygienic assessment of its following parameters: air temperature, radiant temperature, relative humidity, air velocity.

2. Basics

2.1. You should know:

2.1.1. Definition of «microclimate» and factors, which influence its formation.

2.1.2. Physiological basics of human heat exchange and thermoregulation, their dependence on the microclimate: physiological reactions in the comfortable or uncomfortable (hot or cold) microclimate.

2.2. You should have the following skills:

2.2.1. To measure the indoor air temperature, radiant temperature, air humidity and to assess the temperature and humidity conditions of different premises (residential, public/social, industrial).

3. Self-training questions

3.1. Definition of "microclimate" and factors that influence its formation.

3.2. Physiological mechanisms of heat exchange and thermoregulation as factors in the warm-blooded organism thermal status: heat production and loss. The heat loss ways: through respiration and skin, with discharges.

3.3. Chemical mechanisms of heat production (Krebs cycle and others) and physical mechanisms of heat loss: radiation, conduction (convection and conduction), evaporation. The quantity of heat (in percentage) lost by organism by each of these ways in comfortable conditions.

3.4. Laws explaining physical mechanisms of heat loss (Stephan-Boizmann distribution law, the basic law of thermodynamics, the latent heat of evaporation).

3.5. Physiological changes in thermoregulation mechanisms in hot and cold microclimate.

3.6. The air humidity indices: absolute, maximum and relative humidity, physiological humidity, humidity deficit, physiological humidity deficit, dew point and their hygienic significance.

3.7. Devices for measuring the air temperature, radiant temperature, air humidity indices and their operation.

4. Self-training assignments

4.1. The average air temperature in the hospital ward is 18.5°C, at 1.5 meter height - 22 °C and at 0.2 meter height - 16°C, near the inner wall it's 21°C, near the outer wall - 15°C. Daily temperature variation according to the thermograph is from 23°C to 18°C. Assess the thermal conditions in this ward hygienically.

4.2. What is the normal range of the air relative humidity for residential premises?

Choose the correct answer:

1. 20-40%;
2. 20-50%;
3. 30-60%;
4. 35-70%;
5. 40-80%;

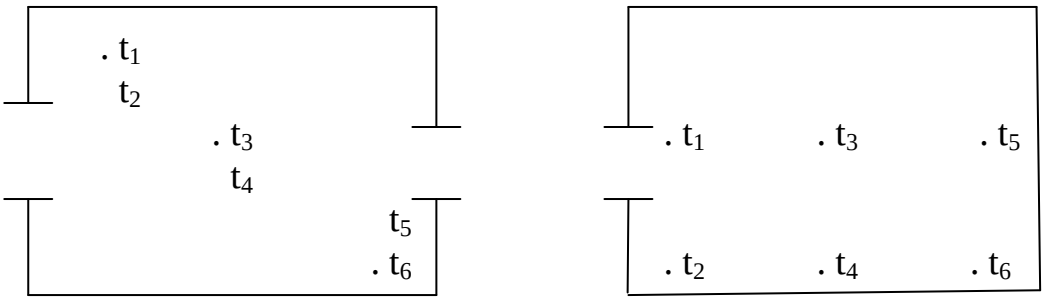
4.3. The Assmann psychrometer's dry thermometer shows 22°C, wet thermometer - 14°C. The atmospheric pressure is 745 Hg mm. Calculate the absolute, maximum and relative air humidity, humidity deficit, physiological humidity deficit, find the dew point.

Appendix 1

Studying the temperature condition of the indoor air

The temperature is measured in 6 or more points to fully characterize the temperature conditions of premises.

Thermometers (mercurial, alcohol, electric or psychrometer dry thermometers) are placed onto support racks at three points 0.2 meter high above the floor, at three points 1.5 meters high (points t_2, t_4, t_6 and t_1, t_3, t_5 respectively) and at 20 cm from the wall along the diagonal section of the laboratory according to the diagram:



a) plan of premises; b) vertical section of premises.

The thermometer data are fixed after 10 minutes of the exposition at the point of measurement.

The air temperature parameters in premises are calculated using following formulas:

a) the average temperature in the premises:

$$\text{a) } t_{aver.} = \frac{t_1 + t_2 + t_3 + t_4 + t_5 + t_6}{6},$$

b) the vertical variation of the air temperature:

$$\Delta t_{vert..} = \frac{t_1 + t_3 + t_5}{3} - \frac{t_2 + t_4 + t_6}{3},$$

c) the horizontal variation of the air temperature:

$$\Delta t_{hor..} = \frac{t_5 + t_6}{2} - \frac{t_1 + t_2}{2}$$

Diagrams and calculations are written down into the protocol, the hygienic assessment is made. It is necessary to consider the following data: the optimal air temperature must be from +18 to +21°C in residential and class-room premises, wards for somatic patients, the vertical temperature variation must be no more than 1.5-2.0°C, horizontal - no more than 2.0-3.0°C. The daily temperature variations are determined using the thermogram, prepared in laboratory using the thermograph. The daily temperature variation must be no more than 6°C.

The allowable and optimal standards of the temperature, presented in the table 1 are the hygienic assessment criteria for residential and public premises.

Table 1

The temperature standards for residential, public and administrative premises

Season	*Temperature*	
	Optimal	Allowable
Warm	20-22°C 23-25°C	No more than 3°C higher than the estimated outdoor air temperature*
Cold and transitional	20-22°C	18 – 22°C**

Comment:

* the allowable temperature is no more than 28°C for public and administrative premises, which are permanently inhabited, for regions with the estimated outdoor air temperature of 25°C and above – no more than 33°C.

** the allowable temperature is 14°C for public and administrative premises where the inhabitants are wearing their street clothes.

The standards were established for people that are continuously staying in the premises for 2 hours or more.

The temperature standards for the workplace air of industrial areas are set in the State Standard #12.1.005-88 “General sanitary and hygienic requirements to the workplace air”, depending on the season (cold, warm) and work category (easy, moderate and hard).

The optimal temperature standards for the cold season are set from 21 to 24°C during the physically easy work and from 16 to 19°C during the physically hard work. These temperature ranges correspond to 22-25°C and 18-22°C during the warm season. The allowable maximum temperature is no more than 30°C for the warm season, the allowable minimum temperature for the cold season is 13°C.

Appendix 2

The radiant temperature and the wall temperature determination

The spherical thermometers are used for the radiant temperature determination in premises, wall thermometers – for the wall temperature determination (see fig. 6.1 a, b)

The spherical thermometer consists of the thermometer located inside the hollow sphere 10-15 cm in diameter and covered with porous polyurethane foam layer. This material has similar coefficients of the infrared radiation adsorption as the human skin.

The radiant temperature is also determined at 0.2 and 1.5 meters above the floor.

The device has the considerable inertia (up to 15 min.), that is why the thermometer data must be taken no earlier than after that time.

The spherical thermometer data at the height of 0.2 and 1.5 m must not vary by more that 3^{o}C in comfortable microclimate conditions.

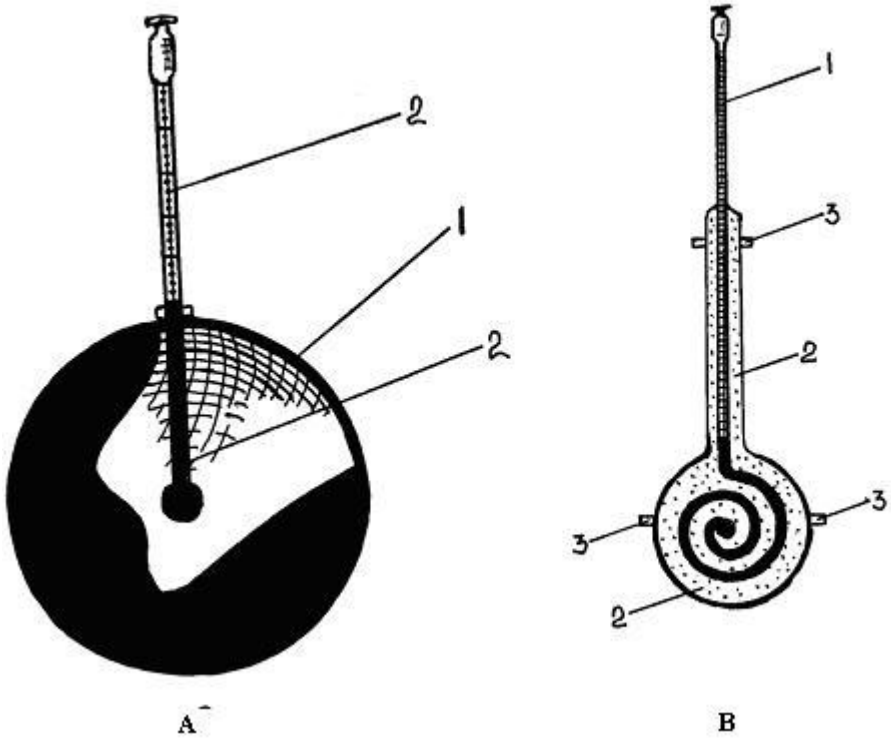


Fig. 6.1. Thermometers for the radiant temperature determination

a – the section of the spherical black thermometer

(1 – 15 cm diameter sphere covered with dull black paint; 2 – thermometer with the reservoir at the center of the sphere)

b – Wall thermometer with the flat turbinal reservoir

(1 – thermometer; 2 – base cover (foam-rubber); 3 –sticky tape)

The values of the radiant temperature below are recommended for different premises (see table 2).

Table 2

Standard values of radiant temperature for different premises

Type of premises	*Radiant temperature, ^oC*
Residential premises	20
Classrooms, laboratories	18
Lecture-rooms. halls	16-17
Gymnasiums	12
Bathrooms, swimming pools	21-22
Hospital wards	20-22
Doctors' consulting rooms	22-24
Operating room	25-30

Special thermometers with the flat turbinal reservoir are used for the wall temperature determination. These thermometers are attached to the wall with special putty (wax with colophony addition) or alabaster. The wall temperature is also determined at 0.2 and 1.5 meters above the floor. In some cases it is necessary to determine the temperature of coldest parts of the wall.

The high levels of infrared irradiation in especially hot manufacture areas are measured using actinometers (solar radiation instrument) and are expressed in mcal/(cm^2×min).

Appendix 3

Determination of the air humidity using psychrometers

The absolute and relative air humidity is determined using the August stationary psychrometer (see fig. 6.2-a).

The reservoir of the psychrometer is filled with water. One of the device's thermometers is wrapped with the fabric. The fabric is put down into the water so that the reservoir is located about 3 cm above the water surface. After this the psychrometer is hanged onto the support at the determination point. The wet and dry thermometer data are taken 8-10 minutes later.

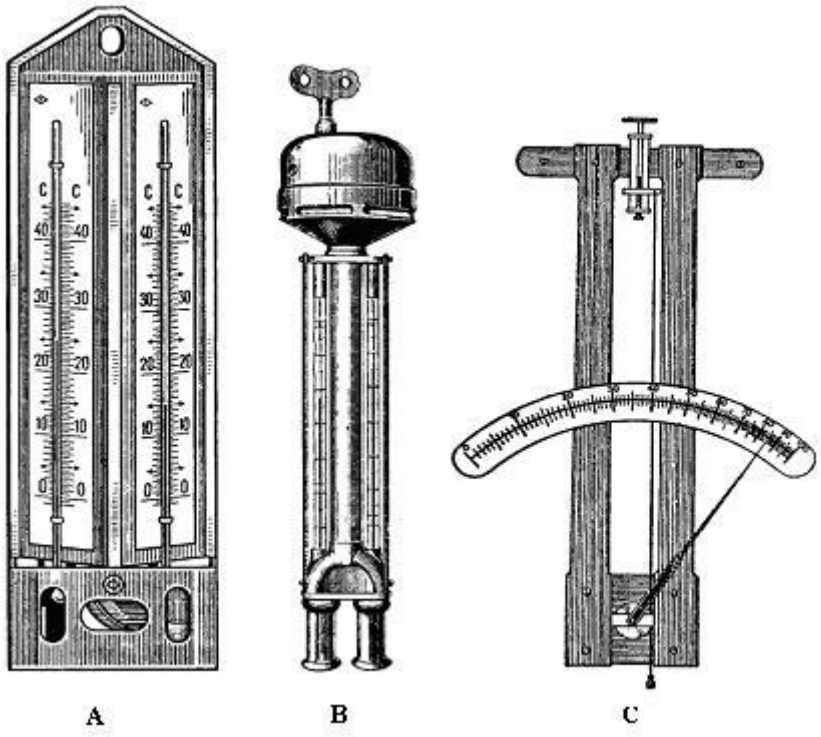


Fig. 6.2. The devices for the air humidity determination
(a - August psychrometer; b – Assmann psychrometer; c – hygrometer)

The absolute humidity is calculated using the Regnault formula:

$$A = f – a \cdot (t - t_1) \cdot B,$$

where, A – the air absolute humidity at the current temperature in Hg mm;
f – maximum pressure of water vapour at the wet thermometer's temperature (see the table of saturated water vapours, table 3);
a – psychrometric coefficient is 0.0011 for enclosed spaces;
t – temperature of the dry thermometer;
t_1 – temperature of the wet thermometer;
B – barometric pressure during the humidity determination, Hg mm.
The relative humidity is calculated using the following formula:

$$P = \frac{A \cdot 100\%}{F},$$

where: P –the value of relative humidity to be found, %;
A – absolute humidity, Hg mm;
F – maximum pressure of water vapour at the dry thermometer temperature, Hg mm (see the table of saturated water vapours, table 3).

Table 3

Maximum pressure of the air water vapour of premises

Air temperature, ^{o}C	Water vapour pressure, Hg mm	Air temperature, ^{o}C	Water vapour pressure, Hg mm
-20	0.94	17	14.590
-15	1.44	18	15.477
-10	2.15	19	16.477
-5	3.16	20	17.735
-3	3.67	21	18.630
-1	4.256	22	19.827
0	4.579	23	21.068
1	4.926	24	22.377
2	5.294	25	23.756
4	6.101	26	25.209
6	7.103	27	26.739
8	8.045	30	31.843
10	9.209	32	35.663
11	9.844	35	42.175
12	10.518	37	47.067
13	11.231	40	53.324
14	11.987	45	71.83
15	12.788	55	118.04
16	13.634	100	760.0

Psychrometric tables for the August psychrometer are used for the relative humidity (RH) determination (if the air velocity is 0.2 m/sec.). The value of RH is found at the point of the dry and wet thermometers data intersection, table 4.

The psychrometer operation is based on the fact that the rate of the water evaporation from the surface of dampened psychrometer's reservoir is proportional to the air dryness. The drier the air – the lower is the wet thermometer's result in comparison to the dry thermometer due to the latent evaporation.

Determination of the relative humidity using the August psychrometer

Dry thermometer data,º C	Wet thermometer data, º C																		
12	5.3	5.7	6.0	6.4	6.8	7.2	7.6	8.0	8.4	8.7	9.1	9.5	9.9	10.3	10.7	11.0	11.3	11.7	12.0
13	5.9	6.4	6.8	7.2	7.6	8.0	8.4	8.8	9.2	9.6	10.0	10.4	10.8	11.1	11.5	11.8	12.2	12.6	13.0
14	6.6	7.1	7.5	8.0	8.4	8.6	9.2	9.7	10.1	10.5	10.9	11.3	11.7	12.1	12.5	12.8	13.2	13.6	14.0
15	7.3	7.8	8.2	8.7	9.2	9.6	10.0	10.5	10.9	11.4	11.8	12.2	12.6	13.0	13.4	13.8	14.2	14.6	15.0
16	8.0	8.5	9.0	9.4	9.9	10.3	10.8	11.3	11.8	12.2	12.6	13.1	13.5	14.0	14.4	14.8	15.6	15.6	16.0
17	8.0	9.1	9.7	10.2	10.7	11.2	11.6	12.1	12.6	13.0	13.5	13.9	14.4	14.9	15.3	15.8	16.2	16.6	17.0
18	9.3	9.9	10.4	10.9	11.4	11.9	12.4	12.9	13.4	13.9	14.4	14.8	15.3	15.7	16.2	16.6	17.1	17.5	18.0
19	10.0	10.6	11.1	11.7	12.2	12.7	13.2	13.8	14.8	14.8	15.3	15.7	16.2	16.7	17.2	17.6	18.1	18.5	19.0
20	10.6	11.2	11.8	12.4	12.9	13.4	14.0	14.5	15.1	15.6	16.1	16.6	17.1	17.6	18.1	18.5	19.0	19.5	20.0
21	11.2	11.9	12.6	13.1	13.6	14.2	14.8	15.3	15.9	16.6	17.1	17.5	18.0	18.6	19.1	19.5	20.0	20.5	21.0
22	11.8	12.5	13.2	13.8	14.4	15.0	15.6	16.1	16.7	17.3	17.9	18.4	18.9	19.5	20.0	20.5	21.0	21.5	22.0
23	12.5	13.1	13.8	14.4	15.1	15.7	16.4	17.0	17.6	18.2	18.8	19.3	19.8	20.4	20.9	21.5	22.0	22.5	23.0
24	13.1	13.8	14.5	15.2	15.9	16.5	17.1	17.8	18.4	19.0	19.6	20.1	20.7	21.3	21.9	22.4	23.0	23.0	24.0
25	13.7	14.5	15.2	15.9	16.6	17.2	17.9	18.5	19.2	19.8	20.5	21.2	21.7	22.2	22.8	23.3	23.9	24.4	25.0
Relative humidity,%	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100

Determination of the air humidity using the Assmann aspiration psychrometer

The significant disadvantage of August psychrometer is its dependence on the air velocity. The air velocity influences the evaporation intensity and the device's wet thermometer cooling.

This disadvantage has been eliminated in Assmann psychrometer due to the usage of the ventilator (see fig. 6.2-b). The ventilator produces the constant air movement at the 4 m/sec speed near thermometers' reservoirs. As a result data does not depend on the air velocity either inside or outside of the premises. Furthermore, thermometers;' reservoirs of this psychrometer are protected with reflecting cylinders around psychrometer's reservoirs from the radiant heat.

The cambric of Assmann aspiration psychrometer wet thermometer is dampened using the pipette, the spring of the aspiration devise is set or the psychrometer with electrical ventilator is plugged in. After these procedures the psychrometer is hung up onto the support at the determination point. The data of wet and dry thermometers are taken 8-10 minutes later.

The absolute air humidity is calculated using the Sprung formula:

$$A = t - 0.5 \times (t_1 - t_2) \times \frac{B}{755},$$

where: A – absolute air humidity in Hg mm;

t – maximum pressure of water vapour at the wet thermometer temperature (see the table of saturated water vapours, table 3);

0.5 – constant psychometric coefficient;

t – temperature of the dry thermometer;

t_1 – temperature of the wet thermometer;

B – barometric pressure at the determination moment in Hg mm.

Relative humidity is determined using the following formula:

$$P = A \times \frac{100}{F},$$

where: P –the value of relative humidity to be found, %;

A – absolute humidity, Hg mm;

F – maximum humidity at the dry thermometer temperature, Hg mm (see table 3).

Relative humidity is determined using the psychrometric tables for aspiration psychrometers. The value of the relative humidity is found at the intersection point of the dry and wet thermometer data (see table 5).

Hair or membrane hygrometers are used for the determination of the relative humidity of the air. These devices measure the relative humidity directly. The hygrometer operation is based on the facts, that the degreased hair lengthens, and the membrane/diaphragm weakens when it's damp, and vice-versa when they are dry (see fig. 6.2-c).

Table 5

Determination of the relative humidity based on the Assmann psychrometer data, %

Dry thermometer indices,° C	Wet thermometer indices, ° C																								
	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.0	22.0	23.0	24.0	25.0	26.0	27.0
8.0	29	40	51	63	75	87	100																			
9.0	21	31	42	53	64	76	88	100																		
10.0	14	24	34	44	54	65	76	88	100																	
11.0		17	26	36	46	56	66	77	88	100																
12.0			20	29	38	48	57	58	78	88	100															
13.0			14	23	31	40	49	59	69	79	89	100														
14.0				17	25	33	42	51	60	70	79	90	100													
15.0					20	27	36	44	52	61	71	80	90	100												
16.0					15	22	30	37	46	54	63	71	81	90	100											
17.0						17	24	32	39	47	55	64	72	81	90	100										
18.0						13	20	27	34	41	49	56	65	73	82	91	100									
19.0							15	22	29	36	43	50	58	66	74	82	91	100								
20.0								18	24	30	37	44	52	59	66	74	83	91	100							
21.0								14	20	26	32	39	46	53	60	67	75	83	91	100						
22.0									16	22	28	34	40	47	54	61	68	76	84	92	100					
23.0									13	18	24	30	36	42	48	55	62	69	76	84	92	100				
24.0										15	20	26	31	37	43	49	56	63	70	77	84	92	100			
25.0											17	22	27	33	38	44	50	57	63	70	77	84	92	100		
26.0											14	19	24	29	34	40	46	52	58	64	71	77	85	92	100	
27.0												16	21	25	30	36	41	47	52	58	65	71	78	85	92	100

Table 4

The relative humidity standards for residential, public and administrative premises (abstract from Building Norms and Rules 2.04.05-86)

Season	*Relative humidity, %*	
	Optimal	Allowable
Warm	30-60	65*
Cold and transitional	30-45	65

Note: * Allowable humidity is 75% for regions with the estimated outdoor air relative humidity more than 75%.

Standards are set for people who continuously stay in premises for more than 2 hours.

Humidity deficit (the difference between the maximum and absolute air humidity) is determined using the table of saturated water vapours. The absolute air humidity, calculated using Regnault or Sprung formulas is subtracted from the value of maximum air humidity according to the dry psychrometer's thermometer.

Physiological humidity deficit (the difference between the maximum air humidity at 36,5^{o}C body temperature and absolute air humidity) is determined using the same table of saturated water vapours (see table 3).

Dew point (temperature when the absolute air humidity is maximum) is determined using the same table of saturated water vapours (see table 3) in reverse direction. The temperature when the absolute air humidity is equivalent to the maximum, is found using the value of absolute humidity.

Interdependency between different air humidity indices can be seen on the diagram (see fig. 6.3).

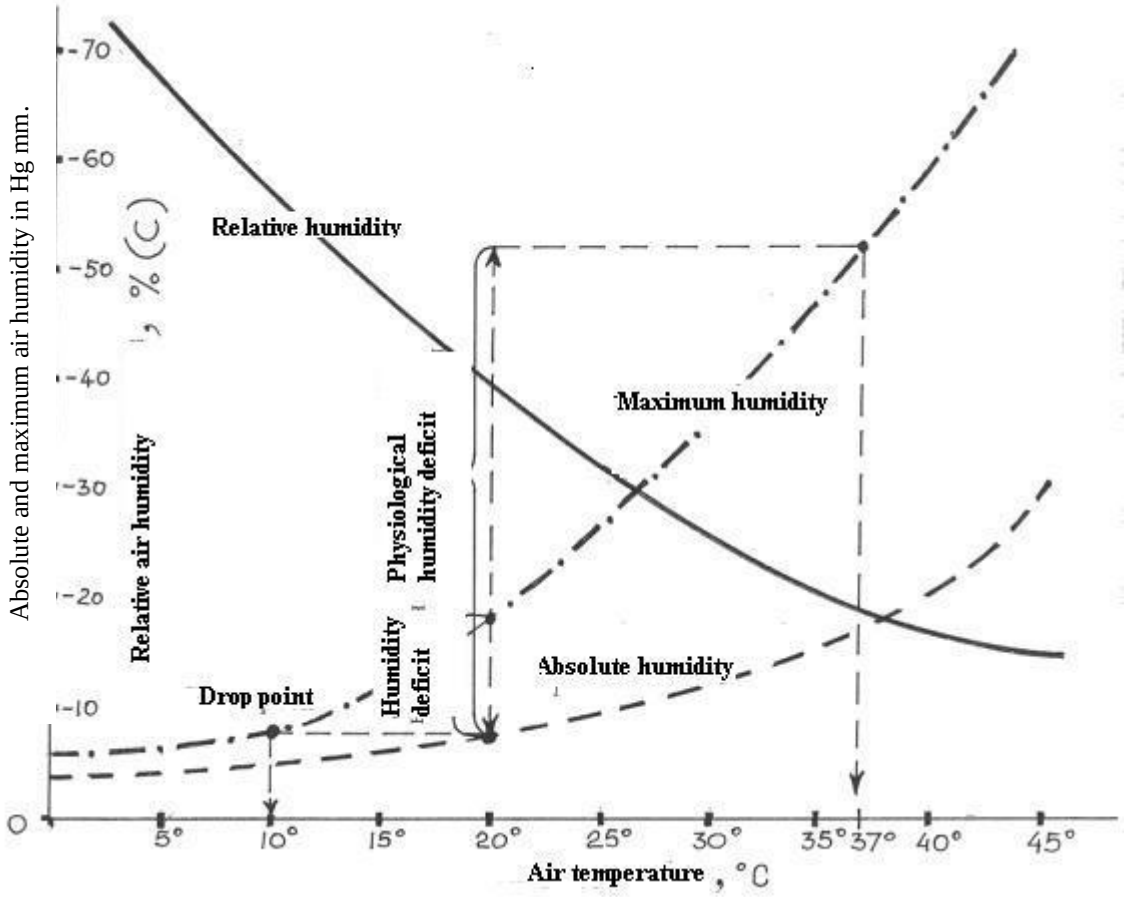


Fig. 6.3. Interdependency between different air humidity indices

The scheme shows, that the rise of temperature provokes the maximum humidity increase in geometric progression, the absolute humidity – in arithmetical progression. When the air temperature rises, the relative humidity is decreases. As a result the amount of water in the air (absolute humidity) is essentially lower in cold seasons than in summer, but is closely related to saturation (maximum humidity). That is why the relative humidity is high in cold seasons and low in summer usually.

The daily temperature, the air humidity and the atmospheric pressure variation are determined using the thermograph, hygrograph and barograph respectively (see fig. 6.4).

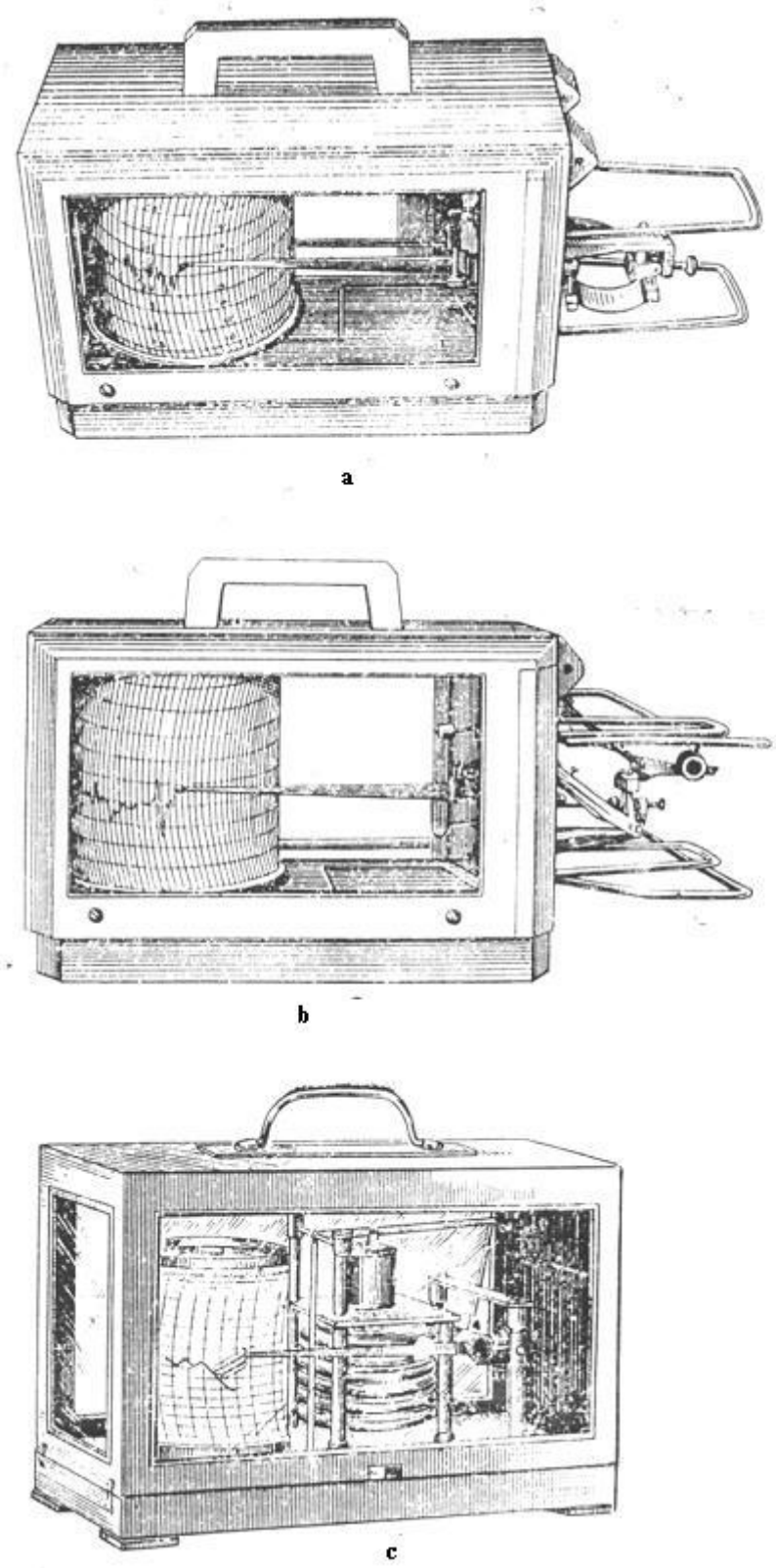


Fig. 6.4. Self-recording devices
(a – thermograph; b – hygrograph; c - barograph.)

Electrothermoanemometer is the combined measurement device and is presented on the figure 6.5.

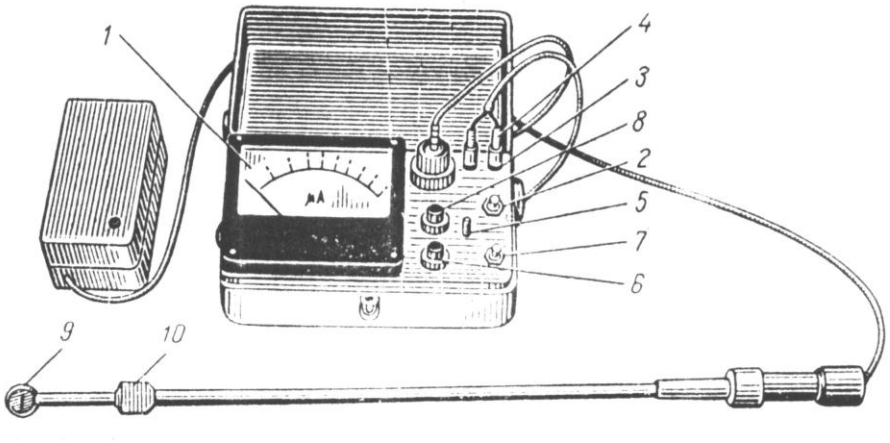


Fig. 6.5. Electrothermoanemometer
(1 – galvanometer; 2 – power switch; 3 – clips for network connection; 4 – sensor plug; 5 – switch for the temperature or air velocity determination; 6 – "measurement-control" switch; 7 – voltage control lever; 8 – sensor (micro-thermistor); 9 – switch protective case.)

Atmospheric pressure is measured using the aneroid barometer. Its scale is graduated in Hg mm or (see fig. 6.6) or in kilopascals.

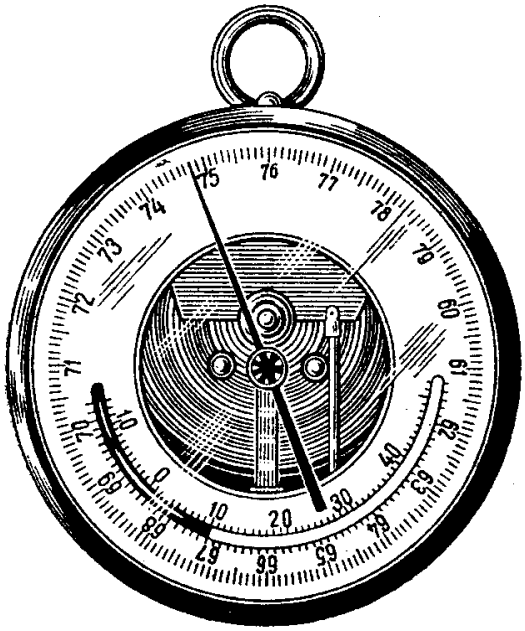


Fig. 6.6 Aneroid barometer

6. Literature

6.1. Principal:

6.1.1. Загальна гігієна. Пропедевтика гігієни. /Є.Г.Гончарук, Ю.І.Кундієв, В.Г.Бардов та ін./ За ред. Є.Г.Гончарука.- К.: Вища школа, 1995.-С. 118-137.

6.1.2. Общая гигиена. Пропедевитика гигиены. Гончарук Е.И., Кундиев Ю.И., Бардов В.Г. и др. – К.: Вища школа, 2000. – С. 217-237.

6.1.3. Загальна гігієна. Посібник для практичних занять. /І.І.Даценко, О.Б.Денисюк, С.Л.Долошицький /За ред. І.І.Даценко. – 2-ге вид. – Львів: „Світ”, 2001. – С. 78-84.

6.1.4. Габович Р.Д., Познанский С.С., Шахбазян Г.Х. Гигиена. – К.: Вища школа, 1983. – С. 36-40, 121-123, 203-207, 270-, 284-285.

6.1.5. Минх А.А. Методы гигиенических исследований. – М.: Медицина, 1971. – С. 11-18.

6.1.6. Даценко І.І., Габович Р.Д. Профілактична медицина: загальна гігієна з основами екології. – 2-ге видання. – Київ: „Здоров’я”, 2004, - С. 106-111.

6.1.7. Lecture materials.

6.2. Additional:

6.2.1. Даценко І.І. Габович Р.Д. Основи загальної і тропічної гігієни. – К.: Здоров’я, 1995. – С. 22-31, 296-297.

6.2.2. ГОСТ 12.1.005-88. “Общие санитарно-гигиенические требования к воздуху рабочей зоны».

NEW REFERENCES

1. Hygiene and ecology: textbook for students of higher medical educational establishments / under the editorship of corresponding member of NAMS of Ukraine, prof. Bardov V.G. – Vinnytsia: Nova Knyha, 2009. – 688 p.

2. Hygiene and ecology / V.A. Korobchanskiy, M.P. Vorontsov, A.A. Musulbas. – Kharkov, 2006. – 207 p.

3. Medicine of emergency situations: textbook for students of higher medical institutions / V.V. Chaplyk, P.V. Oliynyk, S.T. Omelchuk, V.V. Humenyuk. – Vinnytsia: Nova Knyha, 2012. – 344 p.

4. General nutrition: Study guide for the 4th accreditation level Medical School Students / edited by S.T. Omelchuk, O.V. Kuzminska. – Kyiv, 2016. – 146 p.

5. Гигиена и экология: учебник для студентов высших медицинских учебных заведений. – Винница: НОВА КНИГА, 2008ю – 720 с.

7. Equipment required for the lesson

1. Thermometers (alcohol, mercurial, electrothermometer, maximum, minimum, wall).
2. Psychrometers (August stationary, Assmann aspiration).
3. Hygrometers (hair, membrane/diaphragm).
4. Barometer.

5. Self-recording devices (barograph, thermograph, hygrograph).
6. Actinometer (solar radiation instrument).
7. The table of saturated water vapours.
8. The students' task for the assessment of the temperature and humidity conditions of premises.